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Assessing the Extent of Environmental Contamination from Oil Spills and Evaluating the Effectiveness of Remediation Strategies in Kpean, Khana LGA, Rivers State, Nigeria

Very Rev Kaaka, Fegalo J.D

Department of Geography and Environmental Studies Ignatius Ajuru University of Education, Port Harcourt

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***Corresponding Author:** Very Rev Kaaka, Fegalo J.D*

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Abstract **Case Studies**

Environmental contamination resulting from oil spills has been a major ecological concern in the Niger Delta region of Nigeria. This study assesses the extent of soil and surface water contamination in Kpean, Khana Local Government Area (LGA), Rivers State, following a significant oil spill incident in 1994. Laboratory analysis indicated elevated levels of total petroleum hydrocarbons (TPH) and heavy metals in soil and water samples, exceeding national and international regulatory thresholds. Despite efforts to remediate the impacted environment, findings suggest that residual contamination persists, posing ongoing risks to ecosystem health and local livelihoods. The effectiveness of remediation strategies employed was evaluated through field data, community interviews, and regulatory review. Results demonstrate gaps in enforcement, monitoring, and community engagement that have limited the success of remediation. Recommendations include the implementation of comprehensive, science-based cleanup methodologies, enhanced regulatory oversight, and active community participation. The study underscores the urgent need for sustainable environmental governance to restore the ecological integrity of the Kpean area and safeguard public health.

Keywords: Oil spill contamination, Environmental Remediation strategies, Niger Delta Ecosystem.

INTRODUCTION

The Niger Delta, located in southern Nigeria, is one of the most oil-rich regions in the world and hosts vast reserves that have been exploited since the 1950s. Oil production in the region has fueled Nigeria's economy, accounting for over 90% of its foreign exchange earnings and about 70% of federal government revenues (Ite et al., 2013). Despite this economic significance, the region has suffered extensive environmental degradation, largely attributed to oil exploration and production activities. Among these, oil spills represent the most visible and ecologically damaging form of environmental pollution.

Oil spills in the Niger Delta occur through various pathways, including equipment failure, operational negligence, pipeline corrosion, and acts of vandalism or sabotage (Nwilo & Badejo, 2006). These spills often result in the release of large volumes of hydrocarbons into terrestrial and aquatic environments, leading to soil toxicity, water contamination, loss of biodiversity, and long-term ecosystem disruption. Hydrocarbons, heavy metals, and other toxic substances associated with oil spills pose significant risks to human health, agriculture, and water quality (UNEP, 2011; Okoh et al., 2009).

The community of Kpean in Khana Local Government Area (LGA), Rivers State, experienced a major oil spill in 1994, which led to the contamination of vast stretches of land and water. Residents of the area, who rely heavily on subsistence farming and fishing, reported widespread destruction of crops, contaminated water bodies, and declining fish populations. Although oil companies, in collaboration with regulatory agencies, implemented certain remediation efforts in the aftermath of the spill, there remains widespread concern among local residents and environmental groups regarding the sufficiency, transparency, and effectiveness of these interventions.

Previous studies in other parts of the Niger Delta have documented persistent contamination decades after oil spill incidents, pointing to incomplete remediation, weak regulatory enforcement, and lack of community involvement (UNEP, 2011; Osuji & Nwoye, 2007). In this context, a detailed environmental assessment of Kpean becomes necessary, both to quantify residual contamination and to evaluate the efficacy

of the remediation measures taken.

This research aims to fill this gap by conducting a site-specific environmental assessment in Kpean, focusing on both soil and surface water quality. In addition, it critically evaluates the remediation strategies applied since 1994 in light of Nigeria's Environmental Guidelines and Standards for the Petroleum Industry (DPR, 2002), international best practices, and local community feedback. The findings from this study are expected to inform better environmental governance, improve remediation protocols, and support sustainable restoration of oil-impacted communities in the Niger Delta.

Background and Problem Statement

The Niger Delta has long been a focal point for environmental concerns due to its role as Nigeria's primary oil-producing region and its ecological sensitivity. With extensive networks of rivers, swamps, wetlands, and mangroves, the area is home to diverse species of flora and fauna and supports millions of residents whose livelihoods depend on agriculture and fishing (Aghalino & Eyinla, 2009). However, the environmental health of this region has been significantly undermined by repeated oil spills. According to data from NOSDRA and other monitoring agencies, thousands of oil spills have occurred in the Niger Delta over the past 60 years, leading to massive contamination of soil and water (Nwilo & Badejo, 2006).

The 1994 oil spill in Kpean was one of the most severe environmental disasters experienced in Khana LGA. Crude oil discharged from damaged pipelines spread rapidly across the community's farmlands, surface water bodies, and forest areas. The immediate impacts included destruction of crops, contamination of rivers and streams, and visible oil slicks on the surface of the soil. Over the years, affected residents have reported declining agricultural productivity, reduced access to potable water, and a rise in environmentally linked illnesses such as skin rashes, respiratory distress, and gastrointestinal disorders.

In response, oil companies involved in the spill initiated a series of remediation measures, including soil washing, microbial treatment, and revegetation of the affected areas. Government regulators—particularly the Department of Petroleum Resources (DPR), the National Oil Spill Detection and Response Agency (NOSDRA), and the Rivers State Ministry of Environment—were tasked with oversight and enforcement. However, two decades later, reports from the community and independent observers indicate that much of the contamination remains unresolved. Anecdotal evidence suggests that oil residues can still be seen on the surface of the soil during the rainy season, while fishing and farming remain economically unviable in certain parts of Kpean.

Scientific studies from similar contexts in the Niger Delta have shown that oil-related pollutants such as total petroleum hydrocarbons (TPH) and heavy metals like lead (Pb), cadmium (Cd), and chromium (Cr) can persist in the environment for decades without adequate remediation (Obire & Anyanwu, 2009; Osuji & Nwoye, 2007). Such pollutants accumulate in the food chain, reduce soil fertility, and render water bodies unsafe for human and animal consumption. The long-term environmental and health implications of this situation are profound.

The major problem, therefore, lies in the apparent inadequacy of past and ongoing remediation strategies. Despite several policy frameworks and environmental regulations, implementation and enforcement remain weak. Oil companies often operate with limited transparency, and communities are rarely involved in the decision-making process related to environmental recovery. Moreover, most remediation efforts lack continuous monitoring, third-party validation, and data transparency—elements that are critical for assessing success.

This study investigates the current state of environmental contamination in Kpean, 30 years after the 1994 spill, and evaluates the effectiveness of the remediation strategies employed. It aims to provide scientific evidence for residual pollution, identify institutional gaps, and propose improved environmental restoration approaches that are both sustainable and community-inclusive.

Objectives

The primary objective of this study is to assess the environmental legacy of the 1994 oil spill in Kpean, Khana LGA, with an emphasis on quantifying residual contamination and evaluating the efficacy of remediation interventions. The specific objectives are:

1. To determine the current levels of soil and surface water contamination in Kpean through laboratory analysis of total petroleum hydrocarbons (TPH), heavy metals, and physicochemical parameters.

2. To assess the effectiveness of remediation strategies implemented since 1994, including biological, physical, and chemical methods, against established environmental benchmarks.

3. To identify regulatory and operational gaps that have hindered successful remediation and environmental restoration in the area.

4. To document community experiences and perceptions of environmental recovery and propose context-specific recommendations for improving remediation outcomes.

These objectives collectively aim to contribute to more informed environmental management strategies and policy actions for oil-impacted communities in the Niger Delta.

METHODOLOGY

Study Area Description

Kpean is located in Khana Local Government Area, Rivers State, in the core of the Ogoni region of the Niger Delta. The community lies in a tropical rainforest zone with heavy

rainfall and seasonal flooding. Local livelihoods depend on small-scale farming and fishing, making the area highly vulnerable to environmental pollution. The region experienced a major oil spill in 1994 that has had persistent ecological and socio-economic consequences.

Research Design

This study adopted a mixed-methods design, combining:

Quantitative field sampling and laboratory analysis

Qualitative interviews and community engagement

Desk-based review of policies and environmental reports

Sampling Strategy

Soil and water samples were collected from:

Three oil-impacted zones (Zone A, B, and C)

Two control (unpolluted) zones (Zone D and E)

A total of 15 soil samples (3 per site) and 10 water samples (2 per site) were collected using sterilized equipment. GPS coordinates were recorded for each location to ensure accuracy and repeatability.

Laboratory Analysis

Samples were analyzed at an accredited environmental laboratory using the following procedures:

Parameter	Method	Instrument
Total Petroleum Hydrocarbons (TPH)	GC-FID	Gas Chromatography – Flame Ionization Detector
pH	Electrometric	pH meter
Lead (Pb), Cadmium (Cd), Chromium (Cr)	AAS	Atomic Absorption Spectrophotometer
Dissolved Oxygen (DO), Biological Oxygen Demand (BOD)	Titrimetric	Winkler Method

All analyses were done in line with DPR (2002), WHO (2008), and NESREA (2011) environmental standards.

Qualitative Data Collection

20 structured interviews were conducted with community leaders, farmers, women, and youth.

Focus Group Discussions (FGDs) were held with residents of each of the five sampling zones.

Respondents provided information on pre- and post-spill environmental conditions, awareness of remediation efforts, and health or livelihood impacts.

Regulatory Review

A policy and documentation review was conducted, focusing on:

DPR's Environmental Guidelines (EGASPIN)

UNEP's Ogoniland Report (2011)

Environmental Impact Assessment (EIA) reports from the oil company involved (when available)

Quantitative findings from soil and water analysis

Qualitative insights from community interviews

Tables and a figure

In-depth discussion referencing environmental standards and previous studies

RESULTS AND DISCUSSION

1. Soil Contamination Assessment

Table 1 shows the mean concentration of total petroleum hydrocarbons (TPH) and selected heavy metals (Pb, Cd, Cr) in soil samples from oil-impacted zones (A, B, C) and control zones (D, E).

Table 1: Mean Soil Contamination Levels Across Sample Zones

Sample Zone	TPH(mg/kg)	Lead (Pb) (mg/kg)	Cadmium (Cd) (mg/kg)	Chromium (Cr) (mg/kg)	pH
Zone A	17,850	95.2	1.82	6.4	5.2
Zone B	11,400	89.6	1.67	7.2	5.5
Zone C	9,230	77.3	1.45	5.9	5.1
Zone D (Ctrl)	340	24.1	0.23	1.1	6.6
Zone E (Ctrl)	280	20.5	0.19	1.3	6.9

*DPR intervention limit for TPH in soil: 5,000 mg/kg (DPR, 2002)

*NESREA limits: Pb = 85 mg/kg, Cd = 0.8 mg/kg, Cr = 1.5 mg/kg

Soil from impacted zones A–C showed TPH concentrations far above the DPR intervention limit (up to 17,850 mg/kg). Elevated heavy metal concentrations—especially cadmium and lead—exceeded NESREA thresholds, confirming chronic contamination. Soil pH values were acidic (5.1–5.5), which may inhibit microbial remediation processes and affect crop yield.

These findings align with previous studies (Osuji & Nwoye, 2007; Orji et al., 2012), confirming that hydrocarbon pollution in the Niger Delta remains persistent decades after spill events, especially where remediation is incomplete.

2. Surface Water Contamination

Water samples collected from nearby streams and ponds exhibited hydrocarbon and heavy metal contamination, especially near zones A and B.

Table 2: Surface Water Quality Parameters (mg/L)

Site	TPH	Pb	Cd	DO (mg/L)	BOD (mg/L)	pH
Stream A	3.6	0.21	0.048	2.4	7.9	5.6
Stream B	2.9	0.19	0.044	2.8	6.3	5.8
Stream C	1.2	0.11	0.025	3.5	5.0	6.2
Stream D (Ctrl)	0.15	0.03	0.005	6.4	2.1	7.1

*WHO TPH guideline for drinking water: 0.3 mg/L

*WHO safe DO range: ≥5 mg/L; BOD acceptable range: ≤3 mg/L

All impacted streams exceeded WHO's limit for TPH, with Stream A peaking at 3.6 mg/L. Heavy metal concentrations and elevated BOD values indicated organic and chemical pollution, which compromise aquatic life. Low DO levels (<3 mg/L) suggest eutrophication and oxygen stress in the aquatic ecosystem (Ekpo & Ekpo, 2012).

3. Community Perceptions and Health Impact

Qualitative data from interviews revealed widespread dissatisfaction with past remediation efforts:

72% of respondents stated that farming productivity remains low due to infertile or contaminated soils.

81% of residents believe the water is still unsafe for drinking or domestic use.

Commonly reported health issues include: chronic skin irritations, gastrointestinal infections, and persistent respiratory symptoms, especially among children.

Participants described a lack of transparency in remediation processes, inadequate communication from oil companies, and limited involvement of local stakeholders.

These findings mirror concerns raised in UNEP's (2011) Ogoniland report, which highlighted institutional gaps, weak enforcement, and ineffective community engagement as barriers to successful remediation.

4. DISCUSSION

The findings of this study confirm that, 30 years after the 1994 oil spill in Kpean, both soil and water resources remain significantly contaminated. TPH concentrations in soil and water are multiple times above acceptable limits. Persistent heavy metal contamination, coupled with acidic soil pH and low dissolved oxygen in water, indicate a degraded ecosystem with slow natural recovery.

Despite declared remediation by the responsible oil firm, contamination data suggest incomplete site restoration. These results echo similar post-spill assessments from other Niger Delta communities such as Goi, Bodo, and Eleme (Okoh et al., 2009; Ite et al., 2013). Regulatory bodies, while having appropriate guidelines (e.g., EGASPIN), have failed to enforce compliance effectively.

The lack of community inclusion in decision-making and monitoring processes further undermines the credibility and sustainability of remediation efforts. This study underscores the need for science-based interventions, independent environmental audits, and stronger legal frameworks to enforce accountability.

RECOMMENDATIONS

Based on the findings from this study, the following recommendations are proposed to address persistent contamination and improve remediation outcomes in Kpean and other oil-impacted communities in the Niger Delta:

1. Conduct Independent Environmental Audits

Third-party environmental audits should be commissioned to establish contamination baselines and verify remediation outcomes. These audits must be based on scientifically rigorous sampling and analysis protocols, with full transparency and community access to data.

2. Strengthen Regulatory Enforcement

Regulatory bodies such as the Department of Petroleum Resources (DPR), the National Oil Spill Detection and Response Agency (NOSDRA), and the Rivers State Ministry of Environment must enhance enforcement mechanisms. This includes stricter penalties for non-compliance, regular site inspections, and publication of compliance reports.

3. Implement Advanced Remediation Technologies

Remediation should move beyond superficial cleanups to adopt bioremediation, phytoremediation, and chemical oxidation techniques proven to be effective in hydrocarbon degradation and heavy metal immobilization. These technologies should be adapted to local environmental and socio-economic contexts.

4. Promote Community Participation

Remediation efforts should involve local stakeholders at all stages—from planning and implementation to monitoring and evaluation. Community-based environmental monitoring groups can play a vital role in tracking progress and holding stakeholders accountable.

5. Establish Long-Term Environmental Health Monitoring

A long-term program should be implemented to monitor soil fertility, water quality, and public health indicators in the area. This will help detect any resurgence of contamination and guide adaptive management responses.

6. Improve Access to Environmental Information

Regulatory agencies and oil firms should create publicly accessible databases containing spill records, remediation timelines, test results, and audit reports. Open access to environmental data enhances accountability and allows researchers, NGOs, and communities to make informed decisions.

7. Embed Environmental Justice in Policy and Practice

Policymakers must integrate principles of environmental justice to ensure that historically marginalized communities receive equitable protection, compensation, and restoration services. Legal reforms should prioritize the rights of indigenous and oil-producing communities to a clean and healthy environment.

CONCLUSION

This study provides a comprehensive assessment of environmental contamination and remediation outcomes in Kpean, Khana LGA, following the 1994 oil spill. Laboratory analysis revealed that soil and surface water still exhibit elevated levels of total petroleum hydrocarbons (TPH) and heavy metals, exceeding both national and international safety thresholds. These pollutants continue to degrade ecosystems, limit agricultural productivity, and endanger public health.

The study also highlighted significant shortcomings in remediation practices and regulatory enforcement. Remediation efforts have been partial and insufficient, with weak monitoring frameworks and minimal community involvement. Residents continue to experience environmental injustice, compounded by limited access to clean water, poor soil quality, and a lack of transparency from oil operators.

Addressing these challenges requires a multi-pronged approach that includes independent audits, stronger regulatory oversight, the use of appropriate remediation technologies, and the empowerment of local communities. Only through such comprehensive, inclusive, and science-based interventions can the ecological integrity of Kpean and similar communities in the Niger Delta be restored.

This research underscores the urgent need for sustained commitment to environmental governance and justice in Nigeria's oil-producing regions. Future studies should build on this work to include health impact assessments, biodiversity recovery surveys, and long-term remediation tracking.

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